Analytical Abstracts of Current Literature.

SUMMARY OF CURRENT PRE-CAMBRIAN NORTH AMERICAN LITERATURE.[1]

Lawson[2] gives a résumé of the geology of Northeastern Minnesota adjacent to Lake Superior. Surrounding the Lake there are four geological provinces, from the top downward, the Potsdam, Keweenian, Animikie, and Archean.

The Rocks of the Potsdam are flat-lying shaly sandstones, generally of a red color.

The Keweenian occupies the entire Minnesota coast from Duluth to Grand Portage. The series consists in this area of a well stratified series of volcanic flows, having a gentle lakeward dip, which does not generally exceed 10°. The sedimentary formations are represented in the series, but occupy less than one-half per cent of the coast line. The lavas are largely vesicular or amygdaloidal in character, and in those of acid composition in which the vesicular structure is not so well developed are numerous irregular joints. The series has been invaded by many later intrusive masses, which occur as nearly vertical dikes, or more commonly as injected sills which coincide with the planes of stratification of the bedded flows. Since the time of the outflow of the Keweenian rocks, the strata have suffered comparatively little disturbance, the prevalent lakeward dip being probably due to the attitude of the slopes upon which the lavas flowed, rather than entirely to a differential movement of once horizontal strata. The pre-Keweenian labradorite rocks exposed at a number of points were profoundly eroded before the Keweenian was deposited upon them, and they were presumably Archean.

The Animikie rocks occupy the shore of the Lake from Grand Portage to Port Arthur. The series is composed altogether of sedimentary strata, and consists mainly of fine-grained sandstones, which are locally quartzites, carbonaceous shales or slates, and in small part of cherts and jaspers, beds of carbonate of iron, hematite and magnetite, conglomerate, and occasional lenses of non-ferruginous carbonate in the slates. Except in local instances

[1]Continued from p. 118.

[2]Sketch of the Coastal Topography of the North Side of Lake Superior with Special Reference to the Abandoned Strands of Lake Warren, by A. C. Lawson. In 20th Annual Rep. Geol. & Nat. Hist, Sur., Minn. pp. 181-289.

the rocks have been disturbed very little from the horizontal, the average dip of the strata being in a southeasterly direction at an angle probably not exceeding 5 degrees. Intrusive rocks are abundantly present as sills lying parallel to the stratification, resembling contemporaneous beds, and as vertical dikes, some of which have been observed in continuity with the sills. Faulting is a common occurrence in the Animikie, many scarps being due primarily to this cause.

The Archean shares the coast line with the Animikie and Keweenian from the vicinity of Port Arthur to the eastern end of Nipigon Bay, and beyond this point to the outlet of the lake is the dominant series. This complex consists of two divisions: 1) a great volume of profoundly altered sedimentary and volcanic rocks, characteristically schistose or in the form of massive greenstones, which have suffered intense disturbance, and which correspond to what has been designated the Ontarian system, and 2) immense batholites of irruptive gneiss and granite, which have invaded the rocks of the Ontarian system from below in the most irregular fashion, corresponding to that division of the Archean which is commonly recognized as Laurentian. These Laurentian rocks exhibit only to a very subordinate extent those evidences of disturbances and deformation which are so abundantly apparent in the schists which they have invaded. The Laurentian gneisses and granites occupy much more of the shore than do the metamorphic and schistose rocks of the Ontarian. Both divisions of the formation are cut by basic dikes, which, as a rule, do not exceed 100 feet in width, and are vertical or nearly so. The Archean forms the basement upon which the Animikie rests in glaring unconformity, the actual superposition being observed at several points, with the Keweenian lying flat on the latter. Very frequently, however, the Keweenian reposes directly upon the Archean.

Van Hise[1] gives an historical sketch of the Lake Superior region to Cambrian time. The five divisions of this region are the Basement Complex or Archean; The Lower Huronian, Upper Huronian and Keweenawan, the last three together constituting the Algonkian, and the Lake Superior Cambrian Sandstone. Each of these divisions are separated by unconformities.

The Basement Complex consists mainly of granites, gneissoid granites, and of finely foliated dark colored banded gneiss or schist. The relations which obtain between the two divisions are frequently those of intrusion, the granites and gneissoid granites being the later igneous rocks. There is no evidence that any of the dark colored schists are sedimentary, but it is certain, if a massive granular structure be proof of an igneous origin, that a part of them are eruptive, for between the two are gradations.

[1]An Historical Sketch of the Lake Superior Region to Cambrian Time, by C. R. Van Hise. In JOURN. OF GEOL., Vol. I, No. 2, pp. 113-128. With geological map.

The well known characteristic rocks of the Lower Huronian are 1) conglomerates, quartzites, quartz-schists, and mica-schists, 2) limestones, 3) various ferruginous schists, 4) basic and acid eruptives, which occur both as deep seated and as effusive rocks. The order given, with the exception of the eruptives, is the order of age from the base upward. In the Lower Huronian are placed the Lower Vermilion, Lower Marquette, Lower Felch Mountain, Lower Menominee, the cherty limestone formation of the Penokee district, and also probably the Kaministiquia series of Ontario, and the Black River Falls series of Wisconsin.

The formations of the Upper Huronian are 1) a basement slate and quartzite, frequently bearing basal conglomerates, 2) an iron-bearing formation, consisting originally of lean cherty carbonate of iron, calcium and magnesium, and 3) an upper slate. Associated with the sedimentaries in the Michigamme, Crystal Falls, and other districts, are great volcanic series, comprising greenstones, agglomerates, greenstone conglomerates, volcanic ash, and amygdaloids. Where these occur the orderly succession is destroyed. Included in the Upper Huronian are the Penokee, Mesabi, Animikie, Upper Marquette, Upper Menominee, and Upper Felch Mountain districts.

The Keweenawan consists of interstratified lavas, sandstones and conglomerates. The lavas are prevalent at the lower part of the series; interstratifications of the two occur in the middle portions; and the pure detritals exclude the volcanics in the upper portion of the series.

The Lower Huronian is largely crystalline, the Upper Huronian semi-crystalline, and the Keweenawan simply cemented. Locally along axes of intense plication, both the Lower Huronion and Upper Huronian have been transformed into completely crystalline schists. The Cambrian of Lake Superior is a horizontal sandstone, and rests unconformably upon all the preceding.

Smyth[1] describes a contact between the lower quartzite of the Lower Huronian and the underlying granite at Republic, Michigan. Below the lowest exposures of magnetite-actinolite-schist are exposures of the lower quartzite, and below this, hanging upon the northern flank of the granite, is a conglomerate containing very numerous well rounded bowlders of granite and gneiss, identical with the rocks immediatiately below. It is concluded that this conglomerate from its position can not possibly belong to the Upper Huronian, and that it is a true basal conglomerate of the Lower Huronian.

Winchell, N. H.,[2] gives the following as the general consensus of opinions

[1]A contact between the Lower Huronian and the Underlying Granite in the Republic Trough, near Republic, Mich, by H. L. Smyth, JOURN. OF GEOL., Vol. I., No. 3, pp. 268-274.

[2]The Crystalline Rocks, by N. H. Winchell. In 20th Annual Rep. Geol. & Nat. Hist. Sur., Minn., 1891, pp. 1-28.

of several geologists as to the descending succession of the rocks of Northeastern Minnesota.

1. Keweenawan or Nipigon series unconformably beneath rocks bearing the "Dikellocephalus" fauna, and consisting of fragmental and eruptive beds, the upper portions being almost entirely red sandstones.

2. Alternating beds of eruptive sheets and fragmental rocks. The fragmentals are thin bedded slates, actinolite-schists, magnetitic jaspers, cherts and quartzites. The sheets are ordinary eruptives or pyroclastics.

3. Immense quantities of true gabbro often bearing Titaniferous magnetite, are associated with contemporaneous felsites, quartz-porphyries and red granites. This gabbro includes several masses of the next older strata, particularly the Pewabic quartzite.

4. The Animikie. This series is characterized by a great quartzite associated with the iron ores and cherts. The quartzite (Pewabic) lies unconformably on all the older rocks. It often is conglomeratic, bearing debris of the underlying formations. Within it is mingled volcanic tuffs from contemporaneous eruptions. The Pewabic quartzite includes that of Pokegama Falls on the Mississippi River, and of Pipestone County. In the vicinity of contemporaneous volcanic disturbances its grain is fine, like jaspilite, and sometimes it has acquired a dense crystalline structure from contact with the gabbro.

5. The Keewatin. This is a volcanic series of great thickness, being composed mainly of volcanic tuffs, presenting more or less evidence of aqueous sedimentation, but conglomerates, graywackes, quartzitic schists, and glossy serpentinous schists are present. The Kawishiwin formation, apparently the upper member of the series, embraces the great bulk of the greenstones, chloritic schists, jaspers, and hematites. The iron ores are in lenticular lodes, and stand upright conformable with the general position of the rocks.

6. The Keewatin series becomes more crystalline towards the bottom, and passes conformably into completely crystalline mica-schists and hornblende-schists, which are named the Vermilion series. The rocks are usually stratiform, contain magnetic iron ore, and embrace some dark massive greenstone belts, in which no stratification bands are visible.

7. The Laurentian. When not disturbed by upheaval the Vermilion schists pass into Laurentian gneiss, there being a gradual increase in the feldspathic and siliceous ingredients. Even after the Laurentian characters are apparently fully established, conformable bands of Vermilion schists reappear: from which it is plain that the base of the Vermilion is an uncertain plane, which can not be located exactly. This normal passage from the Vermilion to the Laurentian is frequently disturbed by the intrusion of numerous dikes of light colored granitic and basic rocks. These were both in a fluid state, the only non-fluid rocks being the schists which are embraced

within them in isolated pieces. In a similar manner small areas of Laurentian granite, sometimes directly in contact with the schists, have the imperfectly crystalline condition of the Keewatin.

Nos. 3 and 4 are separable from No. 2 by divergence in dip and strike, as well as by a marked difference of lithology. There is consequently some evidence of unconformity between them. Below No. 4 is a great physical break, which separates Nos. 1, 2, 3, and 4 from 5, 6 and 7 throughout the Lake Superior region. This break is the greatest erosion interval which has been discovered in Palæozoic geology. 1, 2, 3, and 4 together constitute the Taconic, Nos. 5, 6, and 7 constitute the fundamental complex or Archean, which is a unit in its grander features.

The structure and origin of the foregoing series are considered in some detail. It is concluded that stratification can always be discriminated from schistosity or slaty cleavage by the varying shades of color bands which sweep across the surface of the rocks, and by gradations in the kind and size of grains across the bands. These layers may vary from 1-16 of an inch to several inches or several feet across.

Comments.—As used by the United States Geologists, Nos. 1, 2 and 3, are included in the Keweenawan. These divisions and the break between 2 and 3 are recognized by Irving, so that the difference is merely one of nomenclature. No. 4 is Upper Huronian; No. 5 is Lower Huronian; and Nos. 6 and 7 are the Basement Complex or Archean. The break between the Lower Huronian and the Basement Complex is perfectly clear on the south shore of Lake Superior, and is found by Lawson at the base of the Keewatin in Ontario. In Minnesota, Professor Winchell, on the contrary, regards the Keewatin as grading down into the underlying series. Many geologists would disagree with the statement that stratification can always be discriminated from schistosity or slaty cleavage by either of the criteria mentioned or by both combined.

Grant,[1] in 1893, publishes his note book, made on a trip in Northeastern Minnesota. The areas visited were those of the Kawishiwi river, Snow Bank lake, Kekequabic lake, and Saganaga lake. In the study of these areas there was no evidence found of a transition from semi-crystalline and crystalline schists into granite. On the other hand, abundant evidence was found of the eruptive nature of the granite rocks into the surrounding sediments. The gneissic and so-called bedded structure in the granitic rocks is not as common as has been supposed, the structure usually being truly granitic. The Kawishiwi river and Snow Bank lake massive rocks are hornblende syenites. The Saganaga rock is a coarse hornblende granite. That

[1] Field Observations on Certain Granitic Areas in Northeastern Minnesota, by U. S. GRANT. In 20th Annual Rep. Geol. and Nat. Hist. Sur. Minn., pp. 35-110.

around Kekequabic lake is a pyroxene granite, and associated with it is peculiar pyroxene-granite-porphyry. The intrusive character of the granite is particularly well shown between Sec. 31 and 32, T. 63 N., R. 10 W., near Clearwater lake, and in the S. E. ¼ of the S. W. ¼ Sec. 26, T. 64 N., R. 9 W., on the west shore of Snow Bank lake. Along the Kawishiwi river, the rocks mapped comprise gabbro, syenite, mica-schist, graywacke, etc.; greenstone and quartz-porphyry. The gabbro is the most recent, and covers part of the older rocks. The syenite is older than the gabbro, and is younger than the greenstone and mica-schist, both of which it cuts. The mica-schists, graywackes, etc., are vertical, and have a general east northeast strike. These have been formerly mapped as belonging to the Vermilion series, but there seems to be good reason for putting all of this type of rock in the area mapped into the Keewatin. The greenstone is presumably of Keewatin age, and is probably younger than the mica-schists, graywackes, etc. Quartz porphyry dikes are found cutting the greenstones in several places, but they have not been seen in the other rocks in the immediate vicinity.

Comments.—The conclusions of this report differ from the general succession given by Professor Winchell in the fundamental point that there is no gradation between the granitic rocks and the metamorphosed sedimentary rocks. Also all of the metamorphosed sedimentary rocks are regarded as belonging to the Keewatin (Lower Huronian?) while the Vermilion schists are not found. If there now exists in this area the original basement upon which the sedimentary rocks were deposited, this has not been found. It is of course possible that such a Basement Complex does not exist in the Kawishiwi river area, the one which was most closely studied, nor even in the entire region, but this is not thought probable.

Winchell (H. V.)[1] describes the Mesabi iron range of Minnesota. The range extends from the Canadian boundary, a little south of west to the Mississippi river, a distance of 140 miles or more, but is concealed for a part of this distance by the later gabbro overflow. The succession of the Mesabi in descending order is:

1. Gabbro unconformably on all the following.....Taconic.
2. Black slates Animikie.....Taconic.
3. Greenish siliceous slates and cherts.....Taconic.
4. Iron ore and taconyte horizon.....Taconic.
5. Quartzite unconformable on 6 and 7.....Taconic.
6. Green schists of the Keewatin.....Archean.
7. Granite or syenite of the Giant's Range.....Archean.

The granite of the Giant's Range is bounded on the north by a belt of crystalline mica-schists and hornblende-schists, and on the south seems to

[1] The Mesabi Iron Range, by H. V. WINCHELL. In 20th Annual Rep. Minn. Geol. Sur., pp. 11-180.

have a direct transition into the green schists of the Keewatin. The green schist has a nearly vertical cleavage. The schists do not always follow the course of the granite range. They are unconformably covered in many places by the quartzite. The quartzite never has a high dip. Near the base it contains pebbles of quartz and granite, as well as jasper and greenstone. This quartzite is correlated with the Pewabic quartzite of the Gunflint lake, the Pokegama quartzite of the Mississippi river, that of Sioux Falls, South Dakota, and that of Baraboo, Wisconsin. Conformable with the quartzite is the iron ore and taconyte horizon. The strata are siliceous and calcareous, and are banded with oxide of iron in beds of variable length and thickness. The ore is sometimes magnetite and sometimes hematite. To the banded jaspery quartzite associated with the ore the term taconyte is applied. The greenish siliceous slates or cherts constitute a transition stage between the rocks of the iron horizon and the black slates. There is a considerable mixture of greenish material, apparently of eruptive origin. The greater part of the rock is a red, yellow, black, white, or green chert, sometimes having a thickness of 200 or 300 feet. It often has a peculiar brecciated appearance, having been shattered into angular fragments, and recemented by the same amorphous silica. The same fracturing is also visible in the iron ore. The siliceous slates and cherts pass upward into a carbonaceous argillite of great thickness, having a dip varying from the horizontal to 20° to the south or southwest. Locally the dip is as high as 45°, in which case the ore deposits lie close to the green schists. The gabbro flow is over all of the previous strata. The effect of the heat on the molten gabbro was to make the iron ore which already existed in the rocks hard and magnetic. There is good reason to believe that the iron ore deposits in their present condition have been principally formed since the gabbro overflow. The ore deposits occur as regular beds, which lie in almost their original positions, usually having a dip of less than 30° and passing into the jaspery quartzite or taconyte in three directions, and occasionally on all sides. The theory of Irving as to the origin of the Gogebic ores is partially adopted. The quartzite is impervious to surface infiltration. The ore is regarded as produced by chemical replacement of some mineral, chiefly silica, by oxide of iron. As evidence of this, all stages of the process may be seen. Iron carbonate is found in the Mesabi rocks, but it does not appear in sufficient quantity to permit the assumption that the source of the ore was originally a carbonate. The solvent for the silica was probably carbon dioxide, and its source may have been the atmosphere, the black slates, recently decaying vegetation, or the ore deposits higher up the hill. The silica removed from the location of the iron ores has been added to the grains of quartz in the quartzite, has been deposited as chalcedonic and flinty silica, and has been deposited in cracks and fissures in the slate, which lie at a lower elevation, but stratigraphically above the ore. The source of

the iron is believed to have been chemical and mechanical oceanic deposits, which have simply concentrated in the present situation, perhaps from rocks now completely removed by erosion. The water which brought in the iron ore to supply the place of the silica taken away in solution followed the natural drainage courses, either the drainage slopes or else the joints. The Giant's Range is regarded as having been uplifted at the time of the gabbro outflows, and to have been caused by them.

Comments.—The succession of the Mesabi range is almost identical with that given by the reviewer for the Penokee-Gogebic district. At the base of the Penokee series constituting the basement complex are granite, syenite, and various green schists. These correspond to Nos. 6 and 7 of the Mesabi. Resting unconformably upon this basement complex is the quartz slate member, consisting largely of quartzite, corresponding to Winchell's No. 5. Resting conformably on the quartzite is the iron-bearing member, which has two main horizons, the lower carrying the ore bodies, and the other free from ore bodies. This iron-bearing formation of non-fragmental origin consists of cherts, slates, and jaspers, all more or less ferruginous. It evidently corresponds exactly to Winchell's Nos. 3 and 4, his "taconyte" being a new name proposed for ferruginous chert, or what the miners call "soft ore jasper." Overlying the iron-bearing member is the upper slate member, which is identical in character with Winchell's Animikie black slates. Unconformably upon the black slates is the Keweenawan series, which, in the Penokee area, has different characters in different places, but to which Winchell's No. 1 gabbro belongs. There thus appears to be absolute identity as to succession, and also the structural breaks occur in precisely the same horizons in the Penokee and Mesabi districts. The facts given as to the iron ores, apart from theory, correspond in nearly every respect with the occurrences in the Penokee district. The differences are that the basement impervious formation in the Mesabi range is not a dike rock, but the pitching quartzite alone. The source of the iron ore is said to be an oceanic deposit, but while the presence of iron carbonate is asserted, it is denied that it can be assumed that it has been present in sufficient quantity to furnish ore beds. The cherty iron carbonate of the Gogebic range, the source of the ore, was a water deposited sediment.

The presence of three like unconformable series in the Penokee and Mesabi districts, the identical succession of the iron-bearing series, the remarkable similarity of the rocks of each of the corresponding formations, and the nearly identical history of the ore-deposits, is a remarkable instance of like conditions prevailing simultaneously in a geological basin throughout a wide area.

Hulst[1] gives a resumé of the general geology of the Menominee district as explained by Brooks, and gives detailed sections of several of the mines. The descending succession at the Millie Ore Body and Chapin Mine is as follows:

Quartzite Jasper Quartzite Quartzite and jasper Quartzite, slate, and jasper Slate Quartzite and slate Quartzite and jasper	140 feet.
Banded ore, containing Millie Ore Body	300 feet
Quartzite and slate Slate	55 feet.
Jasper	170 feet.
Ore body Gray slate	75 feet.
Ore Gray slate Jasper Gray slate Jasper G Gray slate Jasper Ore Gray slate Limestone	185 feet.

The descending succession in the Pewabic Mine is as follows:

Jasper and ore, containing Pewabic Ore Body	215 feet.
Gray slates	112 feet.
Quartz Gray slate Quartzite	77 feet.
Quartz and slate Slate conglomerate	50 feet.
Red slate	77 feet.
Quartz and gray slate Quartzite Quartz and sand Slate conglomerate Quartz conglomerate	116 feet.
Red slate Jasper Red, gray slate Limestone.	

[1] The Geology of that Portion of the Menominee Range East of Menominee river, NELSON P. HULST. In Proceedings Lake Superior Mining Institute for March, 1893, pp. 19-29.

The ore bodies are found in beds of banded lean jasper, which is always an invariable associate of the richer ore, and it may occur anywhere within the jaspery horizon. The rich ore often appears to be a part and parcel of the general stratification of the lean ore encompassing it. Not infrequently one finds spots which are apparently in the transition state from the lean jaspery ore, as though the ore body was charged with a solution, which was gradually dissolving out the silica from the adjacent jasper. There is invariably a notable pitch to the ore bodies, and it is generally to the west at an angle of from 30° to 50°. Connected with some of the ore bodies are well defined hanging or foot-walls of so-called soapstone, but often when there are no well-defined walls, the ore body being found in the jasper, the ore is quite sure to carry a minimum of phosphorus, as exemplified at the Millie, Pewabic, Cyclops, Aragon, and S. E. Vulcan mines. The productive portions of the range appear to be located at the points where the formation has been faulted, eroded deeply, or sharply folded.

Comments.—The sections give additional evidence that in the Menominee district, as in the Marquette, there are two unconformable series. The Chapin, Ludington, and Hamilton appear to belong to the Lower Huronian. The horizon of quartzite, slate and conglomerate is evidently the basal conglomerate of the Upper Huronian. The Mille, Pewabic, and similar ore bodies, are in the Upper Huronian. That the ore bodies occur in disturbed areas, and frequently rest upon soapstone or other impervious formations, accords perfectly with what has been previously ascertained as to the manner of concentration of the Lake Superior iron ores.

Van Hise[1] gives the following as the ascending succession in the iron-producing part of the Marquette district: (1) Basement Complex, consisting of granites, gneisses, schists, and greenstone-conglomerates, the whole intricately intermingled, and the schists intruded by the granites and gneissoid granites; unconformity: (2) Lower Marquette series, having at its base a conglomerate and quartzite formation, upon which rests an iron-bearing formation; unconformity; Upper Marquette series, which looked at broadly is a great shale, mica-slate and mica-schist formation, but it often has at its base quartzites and conglomerates, and several hundred or a thousand feet from its base an iron-bearing formation similar to that of the Lower Marquette series. Included within both the Lower and Upper Marquette series are many basic intrusive dikes and bosses of diabase, and also contemporaneous volcanics, which are largely tufaceous

At the east end of the Marquette district is the Mesnard series, the position of which has not as yet been determined.

[1] The Succession in the Marquette Iron District of Michigan, by C. R. VAN HISE. Bull. Geol. Soc. of Am., Vol. V., 1893, pp. 5–6.

Van Hise[1] describes the Huronian volcanics south of Lake Superior. These include both lavas and tufas interstratified with each other and with contemporaneous clastics. Among the lavas are amygdaloids, the amygdules of which are in certain cases jasper similar to that of the iron formation adjacent, and believed to have been formed at the same jasper forming period. The volcanics are much more altered than those of the Keweenawan. They are found in various places, but the most extensive areas are in the Gogebic district west of Gogebic lake, and in the Michigamme district north of Crystal Falls. In the first locality the series is 7,000 or 8,000 feet in thickness. This great mass of material was piled up, while to the west 700 to 800 feet of the sediments of the iron-bearing formation were accumulating. In this district, therefore, at the same time there was being deposited the ordinary sediments of the area and locally a volcanic series of a wholly different character.

[2]Bayley describes actinolite-magnetite-schist from the Mesabé range of Minnesota. This rock differs from the corresponding schists of the Penokee series only in that quartz is rare and hematite is absent.

C. R. VAN HISE.

[1]The Huronian Volcanics South of Lake Superior, by C. R. VAN HISE. Bull. Geol. Soc. of Am., Vol. IV., pp. 435–36.

[2]Actinolite-magnetite-schists from the Mesabé Iron Range, in Northeastern Minnesota, by W. S. BAYLEY. Am. Jour. of Sci., Vol. XLVI., No. 273, Sept., 1893, pp. 176–180.